forest management note

Note No. 34 Northern Forestry Centre Edmonton, Alberta

# EFFECTS OF CONDITIONING AND STORAGE ON CONTAINERIZED CONIFER SEEDLINGS

## INTRODUCTION

In the prairie provinces, the preferred schedule for rearing containerized conifer seedlings is for the conifers to be seeded in greenhouses in late winter and either planted in the spring and early summer or stored over winter (Carlson 1983). The seedlings are required to be frost-tolerant and of a specified size for outplanting (8–10 cm for lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and 10–13 cm for white spruce (*Picea glauca* (Moench) Voss)). Minimum size (8 and 10 cm) seedlings are considered to be of marginal frost tolerance (Zalasky 1978) and difficult to acclimatize for winter-hardiness.

Frost tolerance of seedlings is promoted by conditioning and hardening-off. The conditioning process is started in 10-week-old or older seedlings by shortening photoperiod and lowering temperature (Zalasky 1983b). Seedlings that are inadequately hardened-off are readily winter-killed or damaged, and the survivors require prolonged rehabilitation of leaders (Zalasky 1978, 1980). According to Carlson (1983), the hardening-off process is started in 8- to 10-week-old or older seedlings in the lathhouse between specific May and August dates depending on the frost-free period within the hardiness zone; however, seedlings do not consistently become dormant during hardening-off if optimum temperatures are unavailable (Zalasky 1983b; Colombo and Glerum 1984). If the seedlings do not become dormant, they are susceptible to damage by freezing temperatures, and bud development may be reduced. To develop optimum frost tolerance, small and large seedlings may require a constant storage temperature for a suitable duration.

Most prairie nurseries have used the lathhouse to provide conditions for developing frost tolerance in seedlings and for overwintering containerized stock. For this study, a satellite field storage shed was developed to maintain containerized stock at −2 to 0°C from November to April (Zalasky 1983a). This Note evaluates winter survival in the lathhouse and storage shed, and winter survival, leader habit, and height growth of containerized lodgepole pine and white spruce following outplanting.

## REARING

In 1980, two conifer species were seeded at 2-week intervals in 40-cm$^3$ Spencer-Lemaire (Ferdinand) containers for a total of eight crops of lodgepole pine and six crops of white spruce (Fig. 1). They were reared in the greenhouse for 11 weeks using fertilization and irrigation procedures outlined by Carlson (1983). Greenhouse temperatures were 21°C during the day and 16°C at night. A 20-h continuous daylight was provided by fluorescent lamps producing 7535 lx.

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## ACCLIMATIZING PROCEDURES

Two procedures (A and B) were used to acclimatize, condition, and harden-off the seedlings. The conditioning procedure utilized the warm, short day and chilling procedures to bring about cold hardiness, a method used by Timmis and Worrall (1975). Two methods of storage were also used; seven crops of seedlings were stored in a field storage shed that had a continuous chamber temperature of −1°C, and seven crops were stored in a lathhouse that had diurnal temperatures throughout the winter months (Fig. 2). The storage shed seedlings were never subjected to temperatures lower than −2°C.

### Procedure A

Of the fourteen crops of seedlings, six crops each of lodgepole pine and white spruce were conditioned under Procedure A. To enhance timing with early November storage requirements (Zalasky 1983a), starting dates for conditioning of the seedlings were 2–6 weeks later than the date of August 20 recommended by Carlson (1983). In Procedure A, four trays of each crop of both the 11-week-old lodgepole pine and white spruce received an 8-h daylight for 9 weeks. During the first 4 weeks, half of the seedlings of each species received a 15°C warm stage of daylight and half received a 20°C warm stage of daylight. All of the seedlings were then chilled at 8°C for 5 weeks (Fig. 1). Irrigation and N-P-K at 44–101–156 ppm were supplied as needed. The seedlings were then stored over winter; two trays of each crop for each species were placed in the field storage shed and were designated AF, and two trays of each crop for each species were placed in the lathhouse and were designated AL. Both the AF and the AL sets of trays contained seedlings of the two different warm treatment stages. Storage was terminated in May 1981. Minimum acceptable heights of 8 and 10 cm were reached by lodgepole pine and white spruce. Mortality was tallied and the dead seedlings were discarded.

### Procedure B

Two crops of lodgepole pine were conditioned under Procedure B. Acclimatization of seedlings began on August 20 as recommended by Carlson (1983). Four trays of each crop of 11-week-old lodgepole pine received an 8-h warm stage of daylight for 4 weeks. Seedlings were then hardened-off under natural conditions in the lathhouse for 5 weeks (Fig. 1). Irrigation and N-P-K at 44–101–156 ppm were supplied as needed. Two trays of each crop of seedlings were placed in the field storage shed and were designated BF, and two trays of each crop were placed in the lathhouse until spring termination date of storage and were designated BL. Both the BF and the BL sets of trays contained seedlings of the two different warm treatment stages. Storage was terminated in May 1981. The minimum acceptable height of 10 cm for lodgepole pine was achieved. Mortality was tallied and the dead seedlings were discarded.

## PLANTING SITE

Seedlings were irrigated and spade-planted on May 12, 1981 in a lodgepole pine clear-cut near Whitecourt, Alberta. A midslope clear-cut was located below the Pimple lookout on a flat aspect of a plateau-benchland on SE Section 13, Township 63, Range 11, west of Meridian 5, at an elevation of 1 048 m. Soil moisture conditions were moist to wet. The loam soil was moderately well drained, had no excess salts, and the levels of nitrate nitrogen, phosphorus, and potassium were sufficient for growth of conifer seedlings. Common limitations of the site were cobblestones, proximity to bedrock, and a natural frost pocket where container seedlings were subjected to frost heave (Walker and Johnson 1980). The location of the clear-cut in the northeastern part of the Boreal foothills was chosen because of its cool summers and frequent chinook and freeze-thaw conditions between October and April (Strong and Leggat 1981). Table 1 shows the ground air temperatures of a clear-cut located in the same general area as the study site.

## WINTER SURVIVAL

Winter survival of seedlings was measured by the percentage of visual damage that occurred in storage and in the field, the percentage of subsequent flushing and leadering, and by height growth. Because of root damage in lathhouse-stored seedlings, outplanted seedlings were examined weekly for retarded flushing and growth defects in 1981 (Zalasky 1978, 1980). The extent of winterkill was determined in the early spring of 1982 and 1983. Field data for dieback, flushing, leadering, and mortality were taken at 7-week intervals from the planting date. Flushing was considered to have failed if none occurred by June 30, 1981, when warm temperatures were favorable for growth. Loss and quality of leadering (Zalasky 1980, 1981) were determined after the winters of 1981–82 and 1982–83 by examining the seedlings for dieback, forking, multiple stem formation, and a lack of leader development.

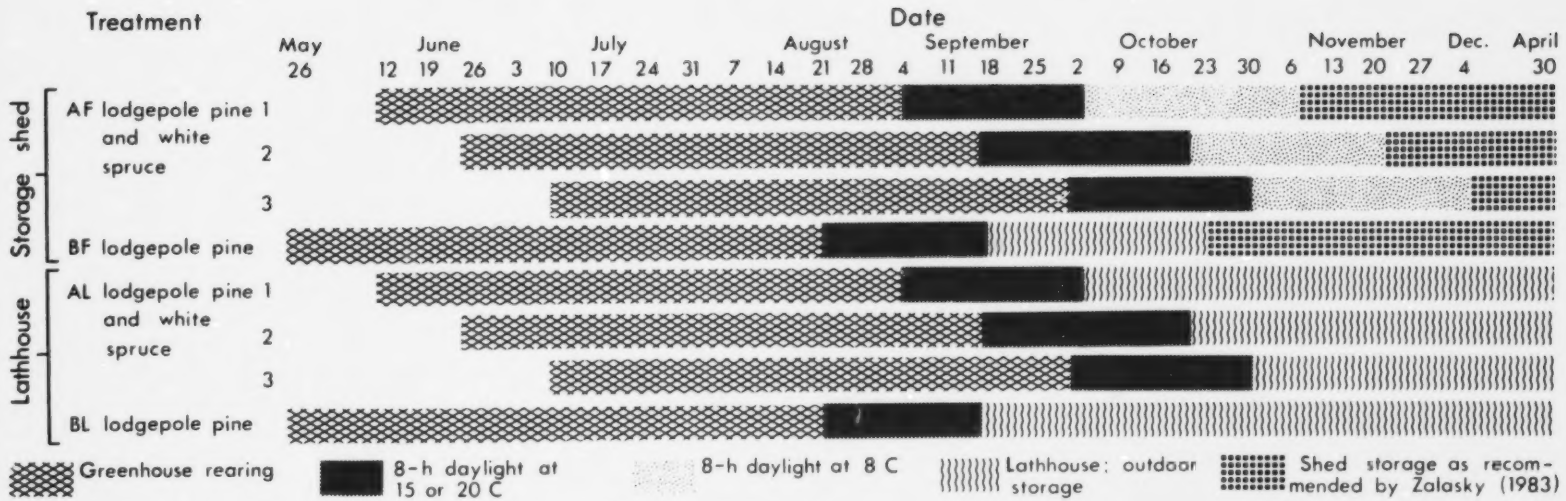


**Figure 1. Lodgepole pine and white spruce rearing, conditioning, and storage schedules in 1980.**



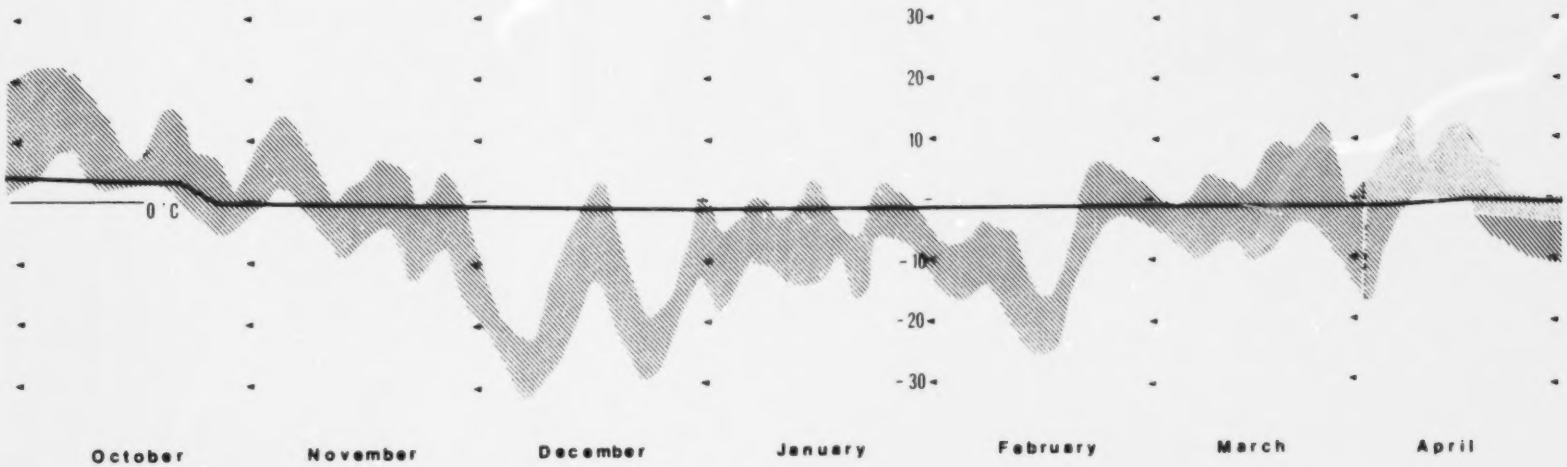


**Figure 2. Storage shed temperatures (horizontal line) and lathhouse temperatures (shaded line), October 1980 to April 1981.**

Quality of leadering was categorized into four habit classes. Habit 1 seedlings were recognized by the presence of dieback, defoliation, frost heaving, basal sweep, and a failure to develop leaders (Fig. 3). Habit 2 seedlings were multiple-stemmed as a result of terminal-bud kill or from failure of the terminal bud to flush (Fig. 4). Habit 2 included Habit 1 seedlings that were experiencing rejuvenation of a single leader. Habit 3 seedlings were forked; they included seedlings that had suffered terminal-bud failure and Habit 2 seedlings that were experiencing leader rejuvenation (Fig. 5). Habit 4 seedlings had normal leaders (Fig. 6), and included fully rejuvenated Habit 3 seedlings.

Height growth of the seedlings was measured in 1983. The height growth data of AF lodgepole pine and of AF and AL white spruce were analyzed by two preliminary means tests, one for the 15°C and 20°C conditioning regimes and one for the three crops (Jeffers 1959). Because no significant differences were found, the data were combined (Table 2).

## EFFECTS OF CONDITIONING AND STORAGE ON SEEDLINGS

During the first 3 weeks of conditioning, growth of 11-week-old seedlings increased noticeably before slowing down and stopping. White spruce stopped growing 3 weeks earlier than lodgepole pine.

Both species survived substantially better in the field storage shed than in the lathhouse. In the storage shed there were no observable differences between the condition of A- and B-conditioned lodgepole pine seedlings and the A-conditioned white spruce seedlings. Average 1981 mortality in storage of AF seedlings was less than 2% for lodgepole pine and less than 1% for white spruce (Table 3). No mortality occurred in BF lodgepole pine. In the lathhouse, AL lodgepole pine suffered 100% mortality, and BL lodgepole pine suffered 89% mortality. Survival of white spruce in the lathhouse was less than satisfactory, although presumably because of its deeper dormancy it survived better than the lodgepole pine. White spruce had an average mortality rate of 65%.

## WINTER SURVIVAL OF STORAGE SHED SEEDLINGS

The AF and BF seedlings survived successfully in the field at Whitecourt, Alberta (Table 2). Storage shed procedure was more effective than the lathhouse procedure in maintaining the viability and timely growth response of seedlings during the 1981 June-July warming. Acclimatizing procedures A and B ensured satisfactory seedling performance in planting areas where temperatures may vary from the general average by 2.8°C every third year (Breadon and Schultz 1973). After the 1981 planting, mortality caused by winterkill resulted in a 2% loss of AF lodgepole pine and a 4% loss of AF white spruce and BF lodgepole pine.

In 1981, flushing was not substantially affected in AF and BF seedlings (Table 2). From 1981 to 1983, Habit 4 leadering did not change appreciably in AF and BF seedlings. Each of the AF and BF lodgepole pine and AF white spruce had a 96% survival rate based on the number planted in 1981, suggesting that the conditioning procedure can be simplified by omitting the 8°C chilling phase. The simplified procedure would consist of a continuous temperature of 20°C during the short-day conditioning and temperatures of −2 to 0°C in storage for hardening-off. This procedure could be applied to small 10-week-old or larger and older seedlings.

## WINTER SURVIVAL OF LATHHOUSE-STORED SEEDLINGS

The AL lodgepole pine was not sufficiently winter-hardy to survive. AL white spruce and BL lodgepole pine suffered high mortality (Table 2). Some winterhardiness was maintained by white spruce under lath and after planting.

Average mortality in lathhouse-stored seedlings was 100% in AL lodgepole pine, 65% in AL white spruce, and 89% in BL lodgepole pine (Table 3). After planting, a high percentage of viable seedlings were winter-killed, leaving few survivors in AL white spruce and even fewer in BL lodgepole pine (Table 2). In 1981, flushing of viable seedlings ranged from 9% in lodgepole pine to 84% in white spruce. In 1982 the percentage of Habit 4 leadering dropped by 27% in AL white spruce and increased by 11% in BL lodgepole pine. The percentage of Habit 4 leadering in white spruce and lodgepole pine increased substantially in 1983. The average height growth of AL white spruce and BL lodgepole pine was lower than that of storage shed (AF) lodgepole pine but not substantially lower than that of storage shed (AF) white spruce.

Conditioning procedures A and B failed to protect physiologically active juvenile seedlings (Zalasky 1978) from −32 to 12°C fluctuating winter temperatures in the lathhouse (Fig. 2) and in the field. Survival was reduced because of a strong tendency towards late growth and

**Table 1. Four-year averages (1972–75) of ground air temperatures in an Edson forest clear-cut[1]**

| Temperature ranges (°C) | Percentage of total monthly hours (%) | | | | | |
|---|---|---|---|---|---|---|
| | May | June | July | August | September | Seasonal average |
| −20 to 0 | 30 | 8 | 2 | 8 | 28 | 15 |
| 1 to 7 | 40 | 36 | 30 | 37 | 36 | 36 |
| 8 to 14 | 20 | 37 | 40 | 33 | 22 | 30 |
| 15 and higher | 10 | 19 | 28 | 22 | 14 | 19 |

[1] Clear-cut located in Section 30, Township 52, Range 25, west of Meridian 5, at 1 042 m elevation.

**Figure 3. Habit 1 white spruce seedling showing leader failure, needle droop, weak shoot growth, and frost heave of root system.**

**Table 2. Winterhardiness, leadering, and height growth of lodgepole pine and white spruce containerized seedlings at Whitecourt, Alberta**

| Conditioning and storage method and species | No. of seedlings planted | 1981 growing season | | | | | | 1982 growing season | | | | | 1983 growing season | | | | | 1983 avg ht of Habit 4 (cm) | % survival in 1983 based on no. planted in 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % mortality[1] | % not flushing | % leadering habit | | | | % mortality | % leadering habit | | | | % mortality | % leadering habit | | | | | |
| | | | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | 4 | | |
| AF[2] lodgepole pine | 572 | 0 | 1 | 0 | 0 | 1 | 99 | 0 | 1 | 3 | 3 | 93 | 2 | 0 | 4 | 4 | 90 | 29 | 96 |
| AF white spruce | 576 | 0 | 1 | 0 | 0 | 0 | 100 | 2 | 0 | 6 | 9 | 83 | 4 | 0 | 5 | 5 | 86 | 22 | 96 |
| AL[3] white spruce | 98 | 20 | 16 | 0 | 0 | 0 | 80 | 20 | 2 | 8 | 17 | 53 | 18 | 0 | 6 | 2 | 74 | 19 | 30 |
| BF[4] lodgepole pine | 184 | 0 | 1 | 0 | 0 | 1 | 99 | 1 | 3 | 6 | 7 | 83 | 4 | 0 | 2 | 1 | 93 | 25 | 96 |
| BL[5] lodgepole pine | 11 | 59 | 91 | 0 | 0 | 27 | 14 | 58 | 0 | 8 | 9 | 25 | 66 | 0 | 0 | 0 | 34 | 20 | 2 |

[1] Current data.

[2] AF = Seedlings received 9 wk of 8-h daylight made up of 4 wk of warm temperature, followed by 5 wk of continuous chilling at 8°C. Seedlings were then placed in the field storage shed.

[3] AL = Seedlings received the same 9-wk conditioning procedure as AF seedlings, but were then placed in the lathhouse for storage.

[4] BF = Seedlings received 4 wk of 8-h daylight at warm temperature, followed by 5 wk of hardening-off in the lathhouse. Seedlings were then placed in the field storage shed.

[5] BL = Seedlings received the same conditioning procedure as BF seedlings, but were left in the lathhouse until spring termination date of storage.

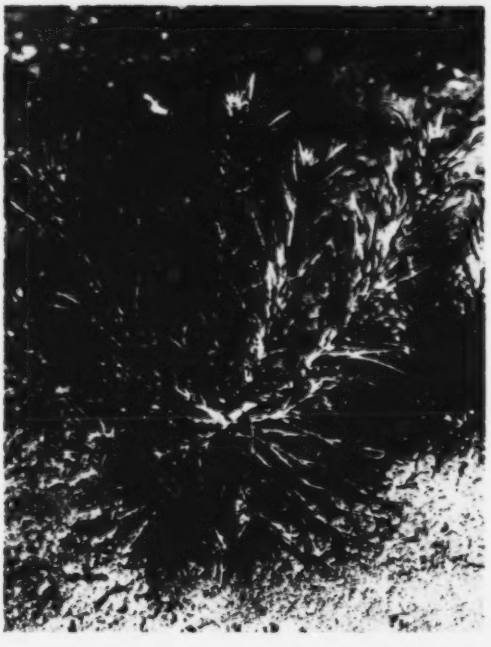

Figure 4. Habit 2 lodgepole pine seedling showing multileadering in second season after planting.

Figure 5. Habit 3 forked white spruce seedling in third growing season.

Figure 6. Habit 4 normal leader in white spruce.

**Table 3. Number of seedlings stored in 1980 and mortality rate in 1981**

| Conditioning treatment and crop | | No. of seedlings stored in 1980 | | Mortality rate in 1981 (%) | |
|---|---|---|---|---|---|
| | | Lodgepole pine | White spruce | Lodgepole pine | White spruce |
| AF[1] | 1 | 190 | 198 | 2 | 0 |
| | 2 | 188 | 193 | 0 | 0 |
| | 3 | 204 | 187 | 3 | 1 |
| BF[2] | 1 | 184 | N/A[3] | 0 | N/A |
| AL[4] | 1 | 97 | 109 | 100 | 60 |
| | 2 | 101 | 97 | 100 | 35 |
| | 3 | 101 | 102 | 100 | 100 |
| BL[5] | 1 | 97 | N/A | 89 | N/A |

[1] AF = Seedlings received 9 wk of 8-h daylight made up of 4 wk of warm temperature, followed by 5 wk of continuous chilling at 8°C. Seedlings were then placed in the field storage shed.

[2] BF = Seedlings received 4 wk of 8-h daylight at warm temperature, followed by 5 wk of hardening-off in the lathhouse. Seedlings were then placed in the field storage shed.

[3] Not applicable.

[4] AL = Seedlings received the same 9 wk procedure as AF seedlings, but were then placed in the lathhouse for storage.

[5] BL = Seedlings received the same conditioning procedure as BF seedlings, but were left in the lathhouse until spring termination date of storage.

development of immature tissues. Seedlings are killed by low temperatures, which cause moisture to freeze in buds, leaves, and stems. In addition to killing tissues, frost affects the chromosomes of cells; the cells of some tissues are stimulated to produce multiple roots and shoots, and cells of other seedlings are crippled so that initiated roots and shoots fail to develop and survive (Zalasky 1978, 1980, 1981).

## CONCLUSIONS

Conditioning and storage shed procedures were effective because seedlings were never subjected to temperatures lower than −2°C. The 9-week conditioning procedure is rather long; however, the storage shed maintains a desirable quality in small seedlings that makes them acceptable for outplanting. B-conditioned lodgepole pine seedlings that were put into the lathhouse August 20 and into the storage shed by October 24 never experienced sufficiently cold temperatures to be negatively affected. Field performance of seedlings was fully satisfactory.

Conditioning and hardening-off under natural conditions were inadequate when seedlings were stored in the lathhouse. The seedlings were not sufficiently winter-hardy to prevent damage from low temperatures. The lodgepole pine put out on August 20 at the recommended time and hardened-off in the lathhouse were able to develop some degree of winterhardiness in storage under lath. Seedlings that survived under lath did poorly after outplanting; lodgepole pine failed, and white spruce had leadering, poor survival, and poor height growth.

## RECOMMENDATIONS

Small containerized seedlings require conditioning with an 8-h daylight and 20°C for 9 weeks and an

overwinter storage at −2°C to become suitable for outplanting. Seedlings can be conditioned in the greenhouse and placed in storage. Seedlings hardened-off in the lathhouse should be placed in an overwinter storage at −2°C a day or more before the start of the freeze-up to avoid damage from freezing and subsequent mortality in storage. Large containerized seedlings may benefit from the same conditioning and storage procedures.

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*August 1986*

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